UNIVERSITI PUTRA MALAYSIA

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By

ADIWIRMAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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March 2006

Chairman: Associate Professor Mohd Razi Ismail, PhD

Faculty: Agriculture

Water is one of the environmental factors that influence plant growth and production. Water is also one of the main components in photolysis during light reaction photosynthesis pathways. Lack of water, therefore, severely decreases plant growth and production.

Several experiments have been conducted to study the effects of water deficit on mangosteen vegetative growth and toward yield production. Experiments were conducted in the green house unit of Faculty of Agriculture, Universiti Putra Malaysia, Serdang, and in Malaysian Agricultural Research and Development Institute (MARDI) station in Kedah Darulaman on young plants (two years old seedlings) and productive plants, respectively. Other experiments with hydrogel (water absorbance and slow release) and partial root drying (PRD) treatments to

increase plant water use efficiency were also conducted. These experiments were conducted at the green house unit of Faculty of Agriculture, Universiti Putra Malaysia, Serdang.

Overall results from these experiments showed that mangosteen plants physiological and biochemical have good response toward water stress or water deficit. Water stress or deficit produced significant decrease in plant leaf water potential, stomatal conductance and photosynthesis rate. Measurements on abscisic acid, peroxidase and proline concentrations were also taken. Water deficits were found to increase mangosteens leaf abscisic acid. However, water stress did not significantly affect plants peroxidase and proline concentration. Water stress also decreased plant leaf increment.

While hydrogel treatment with dose 0.1-0.5 % did not produce positive result, the lower dose (0.02-0.10%) showed good finding, which in these treatment, plant physiological appearance remain normal. It was suggested that hydrogel with dose 0.06 % could to be applied to mangosteen plant to assist the plant conserve soil water availability and increase water used efficiency.

The partial rootzone drying (PRD) treatment showed very interesting findings. PRD treatment was found to reduce water use by 50% compared to normal watering. Reducing water use by 50% in PRD treatment also did not decrease leaf water

potential, stomatal conductance and net photosynthesis. In other words, PRD treatment was able to maintain plants in the normal condition. PRD treatment also significantly produced higher proline concentration than that on water stressed treatment. It is concluded that PRD treatment could be used as water saving for mangosteen in vegetative stage.

Field experiments during the productive stage of mangosteen conducted for two years indicated interesting results. Water stress or deficit increased mangosteen leaves and flag leaves (leaves below flower) total nonstructural carbohydrate (TNC). However, increasing in TNC was not followed by a subsequent increase in fruit yield due to lower fruit set and higher fruit drop percentage. Generally, water stress or water deficit reduced mangosteen fruit yield. Increasing water supply from 50 L/tree/day to 200 L/tree/day in the field water stress significantly enhanced total harvested fruit weight. In the first year of the field experiment, there was no difference in soil moisture. In this condition, raising the amount of irrigation water led to higher average fruit weight. However, in the second year of the field experiment which was drier than the first year, raising the amount of irrigation water did not seem to increase fruit size and average fruit weight. Nevertheless, fruit drop percentage was not affected by the increase amount of irrigation water in the first year, but decreased in the second year of experiment.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGARUH CEKAMAN AIR TERHADAP RESPON FISIOLOGI DAN BIOKIMIA TANAMAN MANGGIS (*GARCINIA MANGOSTANA* L.)

Oleh

ADIWIRMAN

Mac 2006

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Air merupakan salah satu faktor alam yang sangat mempengaruhi tumbesaran dan penghasilan tanaman. Air berfungsi sebagai komponen fotosintesis tanaman dan merupakan media yang dominan dalam tindakbalas fisiologi tanaman. Oleh kerana itu tegasan kerana kekurangan air dapat menurunkan tumbesaran dan pengeluaran tanaman.

Beberapa kajian telah dilakukan untuk mengetahui pengaruh air terhadap tumbesaran tanaman manggis pada peringkat vegetatif dan reproduktif. Secara amnya, kajian telah dilakukan pada tanaman manggis dalam peringkat vegetatif dan tanaman manggis yang telah menghasilkan buah. Eksperimen yang bertujuan untuk meningkatkan keberkesanan penggunaan air (water use efficiency) juga telah

dilakukan dengan menggunakan hidrogel dan pengeringan akar secara berasingan (partial rootzone drying; PRD). Eksperimen pada tanaman manggis pada peringkat vegetatif dilaksanakan di rumah kaca dan eksperimen tanaman manggis pada peringkat penghasilan di ladang buah MARDI Kedah Darulaman.

Keputusan yang diperolehi, secara amnya rawatan tegasan air memberikan kesan kepada fisiologi dan biokimia tanaman manggis. Rawatan tegasan air mengakibatkan penurunan konduksi stomata, potensi air daun dan kadar fotosintesis secara bererti. Pengukuran pengaruh tegasan air terhadap pengawalatur tumbesaran juga telah dilakukan. Rawatan tegasan air meningkatkan secara bererti kadar ABA (abscisic acid) daun manggis. Walau bagaimanapun, rawatan tegasan air tidak memberikan kesan kepada kadar peroksidase tanaman dan prolin secara bererti. Tegasan air juga menurunkan pertambahan ukuran daun manggis.

Rawatan hidrogel pada 0.1-0.5 % tidak memberikan kesan positif yang bermakna, namun pada ekperimen dengan takaran yang lebih rendah yaitu 0.02-0.10 peratus memberikan keputusan yang baik. Takaran hydrogel 0.06% dapat disyorkan untuk digunakan untuk menolong tanaman menjimatkan penggunaan air tanah dan meningkatkan keberkesanan penggunaan air (WUE).

Keputusan yang baik didapatkan pada eksperimen rawatan PRD. Rawatan PRD telah dapat mengurangkan penggunaan air sebanyak 50 % dibandingkan dengan kawalan.

Pengurangan jumlah air pada rawatan PRD tidak menurunkan potensi air daun, konduksi stomata dan kadar fotosintesis. Rawatan PRD juga meningkatkan dengan berkesan kadar prolin tanaman manggis melebihi rawatan tegasan air. Dengan kata lain, rawatan PRD dapat menjaga tanaman dalam kondisi normal.

Percubaan yang dilakukan dua tahun berturut-turut di ladang terhadap tanaman manggis yang reproduktif, menunjukkan keputusan yang baik. Tegasan air secara berkesan meningkatkan kadar 'total nonstructural carbohydrate' (TNC) daun biasa dan daun bendera tanaman manggis. Namun peningkatan tingkat TNC dalam daun tidak diikuti dengan peningkatan hasil buah manggis pada rawatan yang sama. Secara am, tegasan air menurunkan hasil buah manggis. Penggunaan jumlah air yang semakin meningkat dari 50 L/pokok/hari sampai 200 L/pokok/hari pada kondisi tegasan air di ladang, secara berkesan meningkatkan berat hasil buah manggis yang dituai. Pada tahun pertama, yang mana tidak ada perbezaan kelembapan tanah, peningkatan pemberian jumlah air menaikkan purata berat buah. Namun, pada tahun kedua yang mana keadaannya lebih kering dari tahun pertama, pemberian jumlah air yang meningkat tidak meningkatkan saiz buah manggis dan purata berat buah manggis. Walau bagaimanapun, pada tahun pertama bilangan buah gugur tidak dipengaruhi oleh pemberian jumlah air, namun, pada percubaan tahun kedua, peratus buah gugur menurun dengan peningkatan jumlah air yang diberikan.

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I certify that an Examination Committee has met on March 7, 2006 to conduct the final examination of Adiwirman on his Doctor of Philosophy thesis entitled "Effects of Water Stress on the Physiological and Biochemical Responses of Mangosteen (*Garcinia mangostana* L.) Plant", in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follow:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

ADIWIRMAN

Date: 12/06/2006

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LIST OF ABBREVIATIONS

µg	Microgram
ABA	Abscisic acid
ADIP	Alternate drip irrigation
ADP	Adenosine Diphosphate
ANOVA	Analysis of Variance
CAT	Catalase
Chl	Chlorophyll
cm	centimeter
DNA	deoxyribonucleic acid
g	Gram
GAPDH	Glyceraldehyde-3-Phosphate Dehydrogenase
GDH	Glutamate dehydrogenase
GOGAT	Glutamate synthase
GS	Glutamine Synthetase
G_s or g_s	Stomatal Conductance
HPLC	High-performance liquid chromatography
IRGA	Infra-Red Gas Analyzer
LER	Leaf-elongation rate
LSD	Least of Significance Different
LWP	Leaf Water Potential
m	Meter

MARDI	Malaysian Agricultural Research and Development Institute
MDA	Malondialdehyde
mg	Miligram
MPa	Mega Pascal
NAP	National Agricultural Policy
PEO	Polyethilene oxide
PGR	plant growth regulator
POD	Peroxidase
PRD	Partial root-zone drying
PS II	Photosystem II
PVC	Polyvinyl Chloride
PVPP	Polyvinylpyrolidone
RDI	Regulated Deficit Irrigation
RNA	Ribonucleic acid
Rubisco	Ribulose bisphosphate carboxilase, ribulose-1,5-bisphosphate carboxylase/oxygenase
RuBP	Ribulose bisphosphate
RWC	Relative Water Content
SOD	Superoxide Dismutase
SWC	soil water content
TA	Titratable Acid
TLC	Thin Layer Chromatography
TNC	Total Non-structural carbohydrate

TSS	Total Soluble Solid
UV	Ultra Violet
v/v	volume per volume
VPD	Vapour Pressure Deficit
WUE	Water use efficiency

CHAPTER 1

INTRODUCTION

1.1 Background

Mangosteen (*Garcinia mangostana* L.) is known as the "Queen of Fruits". Its origin is in Southeast Asia, probably the Malay Archipelago. It can now be found in Northern Australia, Brazil, Myanmar, Central America, Hawaii, Southern India, Indonesia, Malaysia, Sri Lanka, Thailand, Vietnam, and other tropical countries. Mangosteen is one of the most widely recognized tropical fruits and has universal appeal because of its quality in colour, shape and flavour. The fruit is 2-3 inches (5-7cm) in diameter. A thick reddish-purple rind covers the aril or pulp which is segmented like that of an orange. The white, moist, soft and juicy flesh is sweet and aromatic, has high sugar content, but is low in vitamins and minerals. It is usually eaten fresh, but can be stored for short periods of time. It is also canned, frozen, or made into juice, preserves, and syrup. Mangosteen is also used in pharmaceutical (Kanchanapoom and Kanchanapoom, 1998; Nakasone and Paull, 1998).

Unknown in the wild state, mangosteen is found only as a cultivated female tree (male trees appear non-existent) and may be a fortuitous hybrid between two sister species (*G. malaccensis* and *G. hombroniana*). It is an apomictic polyploidy, which is morphologically intermediate between these two species. Moreover, genetic variation